

**DECLARATION**

I, Masumi Kosaka, a subject of Japan residing in Japan, at the address of 2-88, Hoei-cho, Toyota-shi, Aichi-ken, 470-1201, JAPAN, declare:

That I have thorough knowledge of Japanese and English languages; and that the attached pages contain a correct translation into English of the following Japanese patent application:

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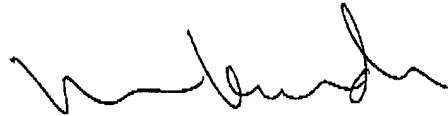
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[LIST OF ATTACHED DOCUMENTS]

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[NAME OF THE DOCUMENT]	Specification	1
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[NAME OF THE DOCUMENT]	Abstract	1
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5

[NAME OF THE DOCUMENT] Specification

[TITLE OF THE INVENTION] CONTROL APPARATUS OF LOCKUP  
CLUTCH AND CONTROL METHOD THEREOF

[CLAIMS]

5 [CLAIM 1]

A control apparatus that controls a lockup clutch of a torque converter while a vehicle equipped with an automatic transmission is coasting in a fuel-cut state, an oil pressure of the lockup clutch being controlled through a feedback control using a hydraulic device so that a slip rotation speed of the lockup clutch matches a target slip  
10 rotation speed, the control apparatus including:

calculation means for calculating the slip rotation speed of the lockup clutch;

and

control means for controlling the hydraulic device so that the oil pressure of the lockup clutch becomes constant if the calculated slip rotation speed is greater than  
15 a predetermined rotation speed when said downshift is executed.

[CLAIM 2]

A control apparatus that controls a lockup clutch of a torque converter while a vehicle equipped with an automatic transmission is coasting in a fuel-cut state, an oil pressure of the lockup clutch being controlled through a feedback control using a  
20 hydraulic device so that a slip rotation speed of the lockup clutch matches a target slip rotation speed, and an oil pressure fixing control being executed so that the oil pressure remains fixed if a downshift of the automatic transmission is executed, the control apparatus including:

calculation means for calculating the slip rotation speed of the lockup clutch;

25 and

and stopping means for stopping the oil pressure fixing control if the calculated slip rotation speed is less than a predetermined rotation speed while the oil pressure fixing control is being executed.

[CLAIM 3]

30 A control apparatus that controls a lockup clutch of a torque converter while a vehicle equipped with an automatic transmission is coasting in a fuel-cut state, an oil pressure of the lockup clutch being controlled through a feedback control so that a slip rotation speed of the lockup clutch matches a target slip rotation speed, the control apparatus including:

calculation means for calculating the slip rotation speed of the lockup clutch;  
and

first rotation speed setting means for setting the calculated slip rotation speed  
as the target slip rotation speed when a downshift of the automatic transmission is  
executed.

[CLAIM 4]

The control apparatus according to claim 3, wherein the first rotation speed  
setting means includes means for setting the calculated slip rotation speed as the  
target slip rotation speed if the calculated slip rotation speed is greater than a  
predetermined rotation speed when the downshift of the automatic transmission is  
executed.

[CLAIM 5]

The control apparatus according to claim 3 or 4, further including second  
rotation speed setting means for setting the predetermined rotation speed as the target  
slip rotation speed if the calculated slip rotation speed is less than the predetermined  
rotation speed.

[CLAIM 6]

The control apparatus according to any one of claims 3 to 5, further including  
converging means for converging the target slip rotation speed to a target slip rotation  
speed of a steady coasting run if a predetermined converging condition has been met.

[CLAIM 7]

A control method for controlling a lockup clutch of a torque converter while a  
vehicle equipped with an automatic transmission is coasting in a fuel-cut state, an oil  
pressure of the lockup clutch being controlled through a feedback control using a  
hydraulic device so that a slip rotation speed of the lockup clutch matches a target slip  
rotation speed, the control methods including:

a calculating step of calculating the slip rotation speed of the lockup clutch;

and

a controlling step of controlling the hydraulic device so that the oil pressure of  
the lockup clutch becomes constant if the calculated slip rotation speed is greater than  
a predetermined rotation speed when said downshift is executed.

[CLAIM 8]

A control method for controlling a lockup clutch of a torque converter while a  
vehicle equipped with an automatic transmission is coasting in a fuel-cut state, an oil

pressure of the lockup clutch being controlled through a feedback control using a hydraulic device so that a slip rotation speed of the lockup clutch matches a target slip rotation speed, and an oil pressure fixing control being executed so that the oil pressure remains fixed if a downshift of the automatic transmission is executed, the control method including:

a calculation step of calculating the slip rotation speed of the lockup clutch; and

a stopping step of stopping the oil pressure fixing control if the calculated slip rotation speed is less than a predetermined rotation speed while the oil pressure fixing control is being executed.

[CLAIM 9]

A control method for controlling a lockup clutch of a torque converter while a vehicle equipped with an automatic transmission is coasting in a fuel-cut state, an oil pressure of the lockup clutch being controlled through a feedback control so that a slip rotation speed of the lockup clutch matches a target slip rotation speed, the control method including:

a calculation step of calculating the slip rotation speed of the lockup clutch; and

a first rotation speed setting step of setting the calculated slip rotation speed as the target slip rotation speed when a downshift of the automatic transmission is executed.

[CLAIM 10]

The control method according to claim 9, wherein the first rotation speed setting step includes a step of setting the calculated slip rotation speed as the target slip rotation speed if the calculated slip rotation speed is greater than a predetermined rotation speed when the downshift of the automatic transmission is being executed.

[CLAIM 11]

The control method according to claim 9 or 10, further including a second rotation speed setting step of setting the predetermined rotation speed as the target slip rotation speed if the calculated slip rotation speed is less than the predetermined rotation speed.

[CLAIM 12]

The control method according to any one of claims 9 to 11, further including a converging step of converging the target slip rotation speed to a target slip rotation speed of a steady coasting run if a predetermined converging condition has been met.

5 [DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD]

This invention relates to a technology for controlling an automatic transmission of a vehicle at the time of a downshift while the vehicle is coasting in a fuel-cut state and, more particularly, to a technology for controlling a lockup clutch provided in a torque converter.

[0002]

[RELATED ART]

While a vehicle is coasting in a fuel-cut state, a control of oil pressure of a lockup clutch is sometimes executed in order to prevent a rapid fall of an engine rotation speed. For example, Japanese Patent Application Laid-Open Publication No. 6-331023 (patent literature 1) discloses a technology in which the oil pressure of the lockup clutch is controlled so that a rotation speed difference ( $=NT-NE$ , hereinafter referred to as "slip rotation speed") between the torque converter turbine rotation speed  $NT$  and the engine rotation speed  $NE$  is kept at a target rotation speed. According to this control, the engine rotation speed is maintained by rotation of the turbine, and therefore does not rapidly fall, so that the fuel-cut state during coasting can be maintained for a long time.

[0003]

25 With reference to FIG. 6, transitions of characteristic values of a vehicle equipped with a related-art control device of a lockup clutch will be described in conjunction with a shift from a fourth speed ratio to a third speed ratio.

[0004]

FIG. 6(A) indicates transitions of the turbine rotation speed  $NT$  and the engine rotation speed  $NE$ . After a 4-to-3 downshift instruction is output at a time point of  $T(0)$ , the turbine rotation speed  $NT$  starts to increase at a time point  $T(2)$  due to engagement of an engaging-side clutch. After an inertia phase begins at a time point  $T(3)$ , the engine rotation speed  $NE$  starts to increase. Note that the inertia phase refers to a stage where the inertia force in an engine rotation system changes. If the



feedback control of the oil pressure of the lockup clutch is not executed, the turbine rotation speed NT increases as the downshift progresses, and reaches the rotation speed of the third-speed running at a time point T(7) (corresponding to a dotted-line portion of NT in FIG. 6(A)).

5 [0005]

FIG. 6(B) illustrates transitions of the slip rotation speed based on the feedback control by the related-art control device. A target slip rotation speed is a rotation speed subject to this oil pressure feedback control. A predetermined constant rotation speed is set as the target slip rotation speed. A calculated slip rotation speed  
10 represents a rotation speed difference at the lockup clutch, that is, the difference between the detected turbine rotation speed NT of the automatic transmission and the engine rotation speed NE (NT-NE).

[0006]

#### [PATENT LITERATURE 1]

15 Japanese Patent Application Laid-Open Publication No. 6-331023

[0007]

#### [PROBLEM TO BE SOLVED BY THE INVENTION]

However, if the aforementioned feedback control is executed at the time of execution of a downshift while the vehicle is coasting in a fuel-cut state, the  
20 following problems may occur.

[0008]

Firstly, the completion of the downshift may be delayed in comparison with the case where the feedback control is not executed. Referring to FIG. 6(A), if the feedback control of the oil pressure of the lockup clutch is executed, the turbine  
25 rotation speed NT begins to decrease at a time point T(4), and then becomes the rotation speed of the 3rd-speed run at a time point T(8) (corresponding to a solid-line portion of NT in FIG. 6(A)). As a result, the time from the downshift until the turbine rotation speed NT reaches a predetermined rotation speed becomes longer, resulting in a delay in completion of the downshift.

30 [0009]

Secondly, a shock may occur due to influence of external disturbances in a temporarily complete engagement state of the lockup clutch, or due to a torque change associated with a rapid rise in the lockup oil pressure. Referring to FIG. 6(B), the calculated slip rotation speed changes in accordance with the difference between

the state of change in NT and the state of change in NE during a time period from T(1) to T(6), and thus, the calculated slip rotation speed deviates from the target slip rotation speed, and a control for bringing the calculated slip rotation speed closer to the target slip rotation speed is executed. That is, there is a problem where a shock is generated due a torque change as a result of the lockup oil pressure being temporarily and rapidly increased, in order to reduce the aforementioned deviation (at a time point T(4) in FIG. 6(C)), or due to external disturbances occurring as a result of the lockup clutch in a temporarily engagement state.

[0010]

Thirdly, degradation of a clutch friction material is caused since an engaging-side clutch (a clutch engaged when establishing the third speed ratio in the aforementioned case) needs to raise the turbine rotation speed to a post-downshift turbine rotation speed. Furthermore, exacerbation of a shock due to the performance of raising the turbine rotation speed is also a problem.

[0011]

The invention has been accomplished in order to solve the above-stated problems. It is an object of the invention to provide a control apparatus for a lockup clutch and a control method thereof, which is capable of preventing a delay in the downshift during a decelerating run of the vehicle in a fuel-cut state, avoiding a completely locked-up state regardless of the situation of a shift, and also suppressing generation of shock.

[0012]

#### [MEANS FOR SOLVING THE PROBLEM]

A control apparatus in accordance with a first invention includes calculation means for calculating a slip rotation speed of a lockup clutch, and control means for controlling a hydraulic device so that an oil pressure of the lockup clutch becomes constant if the calculated slip rotation speed is greater than a predetermined rotation speed when a downshift is executed.

[0013]

According to the first invention, the control apparatus controls an automatic transmission equipped with the lockup clutch and the hydraulic device while a vehicle is coasting in a fuel-cut state. The oil pressure of the lockup clutch is controlled through a feedback control so that the slip rotation speed of the lockup clutch matches a target slip rotation speed. The slip rotation speed herein refers to a

difference between an input rotation speed of the automatic transmission and the rotation speed of a drive power source (e.g., an engine, a motor, etc.). The calculation means of the control apparatus calculates the slip rotation speed of the lockup clutch. If the slip rotation speed is greater than a predetermined rotation speed during  
5 execution of a downshift, the control means controls the hydraulic device so that the oil pressure of the lockup clutch becomes a constant pressure. The period of execution of a downshift corresponds to, for example, a time period from the beginning of the shift to the end thereof, or a time period during which the oil pressure for the shift is within a predetermined range, or the like. Due to the above-  
10 described construction, the lockup clutch is kept in a constant state of engagement. Therefore, it is possible to prevent shock caused by the influence of external disturbance in a temporarily complete engagement state of the lockup clutch during execution of a downshift, or by a torque change associated with a rapid rise in the lockup oil pressure. Furthermore, since the turbine rotation speed can be increased to  
15 a rotation speed corresponding to a downshift while the oil pressure is constant, it is possible to prevent the delay of the downshift caused by a delay in the increase of the turbine rotation speed. Furthermore, in a shift situation that will likely lead to complete engagement of the lockup clutch (e.g., decrease in the slip rotation speed difference), the lockup oil pressure is not fixed, but the normal feedback control is  
20 executed. Therefore, it is advantageous in that complete engagement of the lockup clutch is avoided. Accordingly, it is possible to provide a control apparatus for a lockup clutch which is capable of preventing a delay in the downshift during a decelerating run of the vehicle in the fuel-cut state, avoiding the completely locked-up state regardless of the situation of a shift, and also suppressing generation of shock.

25 [0014]

A control apparatus in accordance with a second invention includes calculation means for calculating a slip rotation speed of a lockup clutch, and stopping means for stopping an oil pressure fixing control if the calculated slip rotation speed is less than a predetermined rotation speed while the oil pressure fixing control is being  
30 executed.

[0015]

According to the second invention, the control apparatus controls the lockup clutch of a torque converter while a vehicle equipped with an automatic transmission is coasting in a fuel-cut state. An oil pressure of the lockup clutch is

controlled through a feedback control so that the slip rotation speed of the lockup clutch matches a target slip rotation speed. If a downshift of the automatic transmission is executed, the oil pressure fixing control is executed so that the oil pressure of the lockup clutch is fixed. If the calculated slip rotation speed is less than  
5 a predetermined rotation speed (i.e., if the lockup clutch becomes engaged more than necessary) while the oil pressure fixing control is being executed, the oil pressure fixing control is stopped. Therefore, it becomes possible to change the oil pressure of the lockup clutch even during execution of a downshift. Therefore, it is possible to avoid a completely locked-up state and prevent the lockup clutch from being engaged  
10 more than necessary (e.g., being completely locked up).

[0016]

A control apparatus in accordance with a third invention includes calculation means for calculating a slip rotation speed of a lockup clutch, and first rotation speed setting means for setting the calculated slip rotation speed as a target  
15 slip rotation speed if a downshift of an automatic transmission is executed.

[0017]

According to the third invention, the control means controls the automatic transmission equipped with the lockup clutch while a vehicle is coasting in the fuel-cut state. An oil pressure of the lockup clutch is controlled through a feedback control  
20 so that the slip rotation speed of the lockup clutch matches the target slip rotation speed. If a downshift of the automatic transmission is executed, the first rotation speed setting means of the control apparatus sets the calculated slip rotation speed as the target slip rotation speed. As a result, during execution of the downshift, the deviation (i.e., difference between the target slip rotation speed and the calculated slip  
25 rotation speed) in the feedback control becomes zero, and a correction amount regarding the oil pressure of the lockup clutch becomes constant. Therefore, the oil pressure of the lockup clutch is kept at a constant pressure. Hence, even if the shift is executed, it is possible to avoid a situation where the oil pressure of the lockup clutch becomes an external disturbance for the shift, and to suppress generation of shift  
30 shock. Furthermore, since the turbine rotation speed smoothly increases to a rotation speed that is needed for completion of the downshift, a delay in the downshift can be prevented.

[0018]

In the control apparatus in accordance with a fourth invention, in addition to the configuration of the third invention, the first rotation speed setting means includes means for setting the calculated slip rotation speed as the target slip rotation speed if the calculated slip rotation speed is greater than a predetermined rotation speed when the downshift of the automatic transmission is executed.

[0019]

According to the fourth invention, if the calculated slip rotation speed is greater than the predetermined rotation speed when the downshift is executed, the calculated slip rotation speed is set as the target slip rotation speed, so that the difference between the slip rotation speed and the target slip rotation speed becomes zero. That is, the deviation in the feedback control becomes zero, and the correction amount regarding the oil pressure of the lockup clutch becomes constant. Therefore, the oil pressure of the lockup clutch is kept at a constant pressure. As a result, a constant state of engagement of the lockup clutch is maintained, so that shock caused by further engagement will be prevented. Furthermore, during this period, the turbine rotation speed can be increased, so that the downshift can be executed without a delay. Still further, in a shift situation that will likely lead to complete engagement of the lockup clutch (e.g., a case where the slip rotation speed becomes less than a predetermined rotation speed), the lockup oil pressure is not fixed. Therefore, it is advantageous in that complete engagement of the lockup clutch is avoided regardless of the situation of a shift, as compared to a case where the feedback control is stopped and the lockup oil pressure is fixed.

[0020]

The control apparatus in accordance with a fifth invention, in addition to the configuration of the third or fourth invention, further includes second rotation speed setting means for setting the predetermined rotation speed as the target slip rotation speed if the calculated slip rotation speed is less than the predetermined rotation speed.

[0021]

According to the fifth invention, if the calculated slip rotation speed is less than the predetermined rotation speed, the predetermined rotation speed is set as the target slip rotation speed. Therefore, the slip rotation speed of the lockup clutch will not decrease below the predetermined rotation speed. As a result, the lockup clutch is

kept in a state of engagement corresponding to the rotation speed, so that the lockup clutch is prevented from being engaged more than necessary.

[0022]

5 The control apparatus in accordance with a sixth invention, in addition to the configuration of any one of the third to fifth inventions, further includes converging means for converging the target slip rotation speed to a target slip rotation speed of a steady coasting run if a predetermined converging condition is met.

[0023]

10 According to the sixth invention, if the predetermined converging condition is met, the target slip rotation speed changes so as to be converged to the target slip rotation speed of a steady coasting. For example, the converging condition may require that the shift be ended and that the torque capacity of a friction engagement element engaged for the downshift be greater than a predetermined capacity, or the like. The convergence of the target slip rotation speed like this way  
15 causes the oil pressure of the lockup clutch to gently change, so that the lockup clutch can be gently engaged. Therefore, it is possible to prevent shock caused by the influence of external disturbance in a temporarily complete engagement state of the lockup clutch in association with a change in the target slip rotation speed, or a torque change associated with a rapid rise in the lockup oil pressure.

20 [0024]

A control method in accordance with a seventh invention includes a calculation step of calculating a slip rotation speed of a lockup clutch and a controlling step of controlling a hydraulic device so that an oil pressure of the lockup clutch becomes constant if the calculated slip rotation speed is greater than a  
25 predetermined rotation speed when a downshift is executed.

[0025]

30 According to the seventh invention, the control method controls an automatic transmission equipped with the lockup clutch and the hydraulic device while a vehicle is coasting in a fuel-cut state. The oil pressure of the lockup clutch is controlled through a feedback control so that the slip rotation speed of the lockup clutch matches a target slip rotation speed. The slip rotation speed herein refers to a difference between an input rotation speed of the automatic transmission and the rotation speed of a drive power source (e.g., an engine, a motor, etc.). The calculation step of this control method calculates the slip rotation speed of the lockup clutch. If

the slip rotation speed is greater than a predetermined rotation speed during execution of a downshift, the control step controls the hydraulic device so that the oil pressure of the lockup clutch becomes a constant pressure. The period of execution of a downshift corresponds to, for example, a time period from the beginning of the shift to the end thereof, or a time period during which the oil pressure for the shift is within a predetermined range, or the like. Due to the above-described control, the lockup clutch is kept in a constant state of engagement. Therefore, it is possible to prevent generation of shock caused by the influence of external disturbance in a temporarily complete engagement state of the lockup clutch during execution of a downshift or a torque change associated with a rapid rise in the lockup oil pressure. Furthermore, since it becomes possible to increase the turbine rotation speed to a rotation speed corresponding to a downshift while the oil pressure is constant, it is possible to prevent the delay of the downshift caused by a delay in the increase of the turbine rotation speed. Furthermore, in a shift situation that will likely lead to complete engagement of the lockup clutch (e.g., decrease in the slip rotation speed difference), the lockup oil pressure is not fixed, but the normal feedback control is executed. Therefore, it is advantageous in that complete engagement of the lockup clutch is avoided. Thus, it is possible to provide a control method for a lockup clutch which is capable of preventing a delay in the downshift during a decelerating run of the vehicle in the fuel-cut state, avoiding the completely locked-up state regardless of the situation of a shift, and also suppressing generation of shift shock.

[0026]

A control method in accordance with an eighth invention includes a calculation step of calculating a slip rotation speed of a lockup clutch, and a stopping step of stopping an oil pressure fixing control if the calculated slip rotation speed is less than a predetermined rotation speed while the oil pressure fixing control is being executed.

[0027]

According to the eighth invention, the control method controls the lockup clutch of a torque converter when a vehicle equipped with an automatic transmission is costing in a fuel-cut state. An oil pressure of the lockup clutch is controlled through a feedback control so that the slip rotation speed of the lockup clutch matches a target slip rotation speed. If a downshift of the automatic transmission is executed, the oil pressure fixing control is executed so that the oil pressure of the lockup clutch

is fixed. If the calculated slip rotation speed is less than a predetermined rotation speed (i.e., if the lockup clutch becomes engaged more than necessary) while the oil pressure fixing control is being executed, the oil pressure fixing control is stopped. Therefore, it becomes possible to change the oil pressure of the lockup clutch even during execution of a downshift. Therefore, it is possible to avoid a completely locked-up state and prevent the lockup clutch from being engaged more than necessary (e.g., being completely locked up).

[0028]

A control method according in accordance with a ninth invention includes a calculation step of calculating a slip rotation speed of a lockup clutch, and a first rotation speed setting step of setting the calculated slip rotation speed as a target slip rotation speed if a downshift of an automatic transmission is executed.

[0029]

According to the ninth invention, the control method controls an automatic transmission equipped with the lockup clutch while a vehicle is coasting in a fuel-cut state. An oil pressure of the lockup clutch is controlled through a feedback control so that the slip rotation speed of the lockup clutch matches the target slip rotation speed. If a downshift of the automatic transmission is executed, the first rotation speed setting step of the control method sets the calculated slip rotation speed as the target slip rotation speed. As a result, during execution of the downshift, the deviation (i.e., difference between the target slip rotation speed and the calculated slip rotation speed) in the feedback control becomes zero, and a correction amount regarding the oil pressure of the lockup clutch becomes constant. Therefore, the oil pressure of the lockup clutch is kept at a constant pressure. Hence, even if the shift is executed, it is possible to avoid a situation where the oil pressure of the lockup clutch becomes an external disturbance for the shift, and to suppress generation of shift shock. Furthermore, since the turbine rotation speed smoothly increases to a rotation speed that is needed for completion of the downshift, a delay in the downshift can be prevented.

[0030]

In the control method in accordance with a tenth invention, in addition to the configuration of the ninth invention, the first rotation speed setting step includes a step of setting the calculated slip rotation speed as the target slip rotation speed if the



calculated slip rotation speed is greater than a predetermined rotation speed when the downshift of the automatic transmission is executed.

[0031]

According to the tenth invention, if the calculated slip rotation speed is greater than the predetermined rotation speed when the downshift is executed, the calculated slip rotation speed is set as the target slip rotation speed, so that the difference between the slip rotation speed and the target slip rotation speed becomes zero. That is, the deviation in the feedback control becomes zero, and the correction amount regarding the oil pressure of the lockup clutch becomes constant. Therefore, the oil pressure of the lockup clutch is kept at a constant pressure. As a result, a constant state of engagement of the lockup clutch is maintained, so that shock caused by further engagement will be prevented. Furthermore, during this period, the turbine rotation speed can be increased, so that the downshift can be executed without a delay. Still further, in a shift situation that will likely lead to complete engagement of the lockup clutch (e.g., a case where the slip rotation speed becomes less than a predetermined rotation speed), the lockup oil pressure is not fixed. Therefore, it is advantageous in that complete engagement of the lockup clutch is avoided regardless of the situation of a shift, as compared to a case where the feedback control is stopped and the lockup oil pressure is fixed.

[0032]

The control method in accordance with an eleventh invention, in addition to the configuration of the ninth or tenth invention, further includes a second rotation setting step of setting the predetermined rotation speed as the target slip rotation speed if the calculated slip rotation speed is less than the predetermined rotation speed.

[0033]

According to the eleventh invention, if the calculated slip rotation speed is less than the predetermined rotation speed, the predetermined rotation speed is set as the target slip rotation speed. Therefore, the slip rotation speed of the lockup clutch will not decrease below the predetermined rotation speed. As a result, the lockup clutch is kept in a state of engagement corresponding to the rotation speed, so that the lockup clutch is prevented from becoming engaged more than necessary.

[0034]

The control method in accordance with to a twelfth invention, in addition to the configuration of any one of the ninth to eleventh inventions, further includes a

converging step of converging the target slip rotation speed to a target slip rotation speed of a steady coasting run if a predetermined converging condition is met.

[0035]

According to the twelfth invention, if the predetermined converging condition is met, the target slip rotation speed is changed so as to be converged to the target slip rotation speed of a steady coasting. The converging condition may require, for example, that the shift be ended that the torque capacity of a friction engagement element engaged for the downshift be greater than a predetermined capacity, or the like. The convergence of the target slip rotation speed like this way causes the oil pressure of the lockup clutch to gently change, so that the lockup clutch can be gently engaged. Therefore, it is possible to prevent shock caused by the influence of external disturbance in a temporarily complete engagement state of the lockup clutch in association with a change in the target slip rotation speed or a torque change associated with a rapid rise in the lockup oil pressure.

[0036]

#### [EMBODIMENT OF THE INVENTION]

An embodiment of the invention will be described hereinafter with reference to the accompanying drawings. In the description below, like component parts are represented by like reference characters. They will have the same names and functions. Therefore, repeated description of them will be avoided.

[0037]

FIG. 1 shows a diagram illustrating control blocks of a control apparatus according to an embodiment of the invention. A vehicle in which the control apparatus is mounted includes an ECT\_ECU (Electronically Controlled Automatic Transmission-Electronic Control Unit) 100, an engine 110, a torque converter 120, an automatic transmission 200, and sensors that are interconnected. The automatic transmission 200 includes an oil pump 202, a pressure regulating valve 204, and a speed change mechanism 300. The torque converter 120 includes a lockup clutch 122, the oil pressure of which is controlled by a lockup control valve 158. The discharge pressure by the oil pump 202 is adjusted by the pressure regulating valve 204, whereby a predetermined oil pressure is supplied to the speed change mechanism 300 and the lockup control valve 158 via a hydraulic circuit (not shown).

[0038]

The engine 110 is provided with a water temperature sensor 152, a throttle opening sensor 154, and an engine speed sensor 156. The automatic transmission 200 is provided with an input rotation speed sensor 164, an output rotation speed sensor 166, and an oil temperature sensor 168. The ECT\_ECU 100 receives signals from the water temperature sensor 152, the throttle opening sensor 154, the engine speed sensor 156, the input rotation speed sensor 164, the output rotation speed sensor 166, and the oil temperature sensor 168. The ECT\_ECU 100 controls the engagement state of the lockup clutch 122 by outputting signals to the lockup control valve 158 to control the oil pressure.

[0039]

FIG. 2 illustrates the configuration of a drive train of a vehicle equipped with the control apparatus according to the embodiment of the invention. The drive train includes the torque converter 120 and the speed change mechanism 300.

[0040]

Referring to FIG. 2, the torque from the engine (not shown) is input to the torque converter 120 via an input shaft 126. The torque converter 120 is provided with the lockup clutch 122. The engagement state thereof is controlled on the basis of a predetermined condition. The torque transmitted from the torque converter 120 is transferred to a transmission input shaft 208 via a turbine runner 124, and then is input to the speed change mechanism 300 of the automatic transmission 200. If a predetermined condition is fulfilled, the speed change mechanism 300 establishes a speed stage corresponding to the condition and thus transmits torque, outputting the torque to a transmission output shaft 210.

[0041]

FIG. 3 is an application chart of engagement elements of the automatic transmission 200 according to the embodiment of the invention. "C0" to "C3" and "B0" to "B2" all represent friction engagement elements. Symbol "O" indicates that a friction engagement element is currently engaged. The torque input to the automatic transmission 200 is transmitted via these friction engagement elements. Symbol "x" indicates that a friction engagement element is currently released. For example, if the vehicle establishes a fourth speed ("4th" in FIG. 3), the friction engagement elements "C2", "B0" and "B1" are engaged.

[0042]

With reference to FIG. 4, the control configuration of a program executed by the control apparatus according to the embodiment of the invention will be described based on a flowchart.

[0043]

5 In step (hereinafter, simply referred to as "S") 102, the ECT\_ECU 100 reads signals input from the individual sensors. These signals indicate the degree of throttle opening, the engine rotation speed, the input rotation speed, the output rotation speed, the shift position, etc.

[0044]

10 In S104, the ECT\_ECU 100 determines whether a lockup slip control is being executed. This determination is performed based on the signals input in S102. The lockup slip control herein refers to a feedback control of the oil pressure of the lockup clutch 122 based on the slip rotation speed difference at the lockup clutch 122 while the vehicle is coasting in a fuel-cut state. If the lockup slip control is being  
15 executed (YES at S104), the process proceeds to S106. If it is not (NO at S104), the process ends.

[0045]

In S106, the ECT\_ECU 100 determines whether a 4-to-3 downshift instruction has been detected. This determination is performed on the basis of, for  
20 example, whether the running state of the vehicle detected from the signals input in S102 has changed from a region of the 4th speed to a region of the 3rd speed, or whether the shift position sensor signal has switched from the 4th speed to the 3rd speed, etc. If a downshift instruction is detected (YES at S106), the process proceeds to S108. If it is not (NO at S106), the process ends.

25 [0046]

In S108, the ECT\_ECU 100 controls oil pressures for a 4-to-3 downshift. That is, the ECT\_ECU 100 starts to discharge pressure in order to release the friction engagement element "B1", and starts to increase oil pressure for engaging the friction engagement element "C1". In this case, the oil pressure to the friction engagement  
30 element "B1" is gently reduced in concert with the increase in the oil pressure of the friction engagement element "C1". The oil pressure to the friction engagement element "C1" is gently increased until the shift completes, in order to suppress generation of an engagement shock.

[0047]

In S110, the ECT\_ECU 100 detects the operation state of the automatic transmission 200. The operation state herein refers to the input and output rotation speeds, the oil pressures of the friction engagement elements "B0" and "C1", the duty ratio for a duty solenoid 160, etc.

5 [0048]

In S112, the ECT\_ECU 100 determines whether a condition for starting to change a target slip rotation speed (hereinafter, referred to as "starting condition") has been fulfilled, on the basis of the operation state detected in S110. This determination is performed on the basis of, for example, whether the shift has begun, whether the degree of progress of the shift is greater than or equal to a predetermined value, whether the inertia phase has begun, whether the engaging-side oil pressure is greater than or equal to a predetermined value, whether the engaging-side duty ratio has exceeded a predetermined value, whether the engaging-side clutch capacity is greater than or equal to a predetermined value, or the like. Note that the inertia phase refers to a stage where the inertia force of the engine rotation system changes. As the inertia phase begins, the input rotation speed of the automatic transmission 200 starts to change. If the starting condition has been fulfilled (YES at S112), the process proceeds to S114. If it is not (NO at S112), the process proceeds to S110.

15 [0049]

In S114, the ECT\_ECU 100 calculates a slip rotation speed ( $=NT-NE$ ) at the lockup clutch 108 on the basis of the operation state detected in S110 (i.e., the rotation speed NE of the engine 110 and the input rotation speed NT of the automatic transmission 200).

20 [0050]

In S116, the ECT\_ECU 100 determines whether the slip rotation speed calculated in S114 (hereinafter, referred to as "calculated slip rotation speed") is greater than or equal to a predetermined reference rotation speed. The reference rotation speed is, for example, a minimum necessary slip rotation speed that is needed in order to prevent the lockup clutch from being engaged more than necessary. If the calculated slip rotation speed is greater than or equal to the reference rotation speed (YES at S116), the process proceeds to S118. If it is not (NO at S116), the process proceeds to S120.

25 [0051]

In S118, the ECT\_ECU 100 sets the calculated slip rotation speed as the target slip rotation speed. As a result, the slip rotation speed (i.e., the deviation in the lockup slip control) becomes zero.

[0052]

5 In S120, the ECT\_ECU 100 sets the reference rotation speed as the target slip rotation speed. Therefore, the oil pressure of the lockup clutch 122 is kept at an oil pressure corresponding to the reference rotation speed, so that state of engagement of the lockup clutch 122 is kept constant.

[0053]

10 In S122, the ECT\_ECU 100 detects the state of operation of the automatic transmission 200. The state of operation refers to the input and output rotation speeds, the oil pressures of the friction engagement elements "B0" and "C1", the duty ratio for the duty solenoid 160, etc.

[0054]

15 In S124, the ECT\_ECU 100 determines whether a condition (hereinafter, referred to as "converging condition") for converging the target slip rotation speed to a target slip rotation speed set at a time of steady coasting (hereinafter, referred to as "steady target rotation speed") is fulfilled. This determination is performed on the basis of whether the shift has ended, whether the degree of progress of the shift is  
20 greater than or equal to a predetermined value, whether the engaging-side oil pressure is greater than or equal to a predetermined value, whether the engaging-side duty ratio has exceeded a predetermined value, whether the engaging-side clutch capacity is greater than or equal to a predetermined value, or the like. If the converging condition has been met (YES at S124), the process proceeds to S126. If it is not (NO  
25 at S124), the process proceeds to S122.

[0055]

In S126, the ECT\_ECU 100 gradually brings the target slip rotation speed closer to the steady target rotation speed. If the target slip rotation speed reaches the steady target rotation speed, the steady target rotation speed is set as the target slip  
30 rotation speed.

[0056]

An operation of the control apparatus in accordance with the embodiment of the invention based on the above-described configuration and the flowchart will be

described. A case where the automatic transmission down-shifts from the 4th speed to the 3rd speed while the vehicle is coasting in the fuel-cut state will be explained.

[0057]

5 If signals are read during a decelerating run (S102) and the lockup slip control is being executed (YES at S104) and the ECT\_ECU 100 detects a 4-to-3 downshift instruction (YES at S106), the control of oil pressure for the downshift is started (S108).

[0058]

10 Then, the ECT\_ECU 100 detects the state of operation, such as the input and output rotation speeds of the automatic transmission 200, the working oil pressures of the friction engagement elements, etc. (S110). If the starting condition has been met (YES at S112), the ECT\_ECU 100 calculates the slip rotation speed of the lockup clutch 108 (S144). If the calculated slip rotation speed is greater than or equal to the reference rotation speed (YES at S116), the ECT\_ECU 100 sets the  
15 calculated slip rotation speed as the target slip rotation speed (S118). As the downshift progresses, the input and output rotation speeds of the automatic transmission 200, the working oil pressures of the friction engagement elements, or the like are detected (S122). If the converging condition has been met (YES at S124), the ECT\_ECU 100 gradually converges the target slip rotation speed to the steady  
20 target rotation speed (S126). After that, the ECT\_ECU 100 sets the steady target rotation speed as the target slip rotation speed, and continues the lockup slip control during the steady run.

[0059]

25 FIG. 5 illustrates the transitions of characteristic values of a vehicle equipped with the control apparatus according to the embodiment of the invention. FIG. 5(A) illustrates the transitions of the engine rotation speed NE and the turbine rotation speed NT of the automatic transmission 200. At a time point T(1), a 4-to-3 downshift instruction is output. When the turbine rotation speed NT has started to increase as the shift progresses, the inertia phase begins (time point T(2)). At a time  
30 point T(3), the turbine rotation speed NT reaches the rotation speed corresponding to the 3rd-speed run. Thus, the shift ends. On the other hand, the engine rotation speed NE starts to increase with a delay after the inertia phase begins. At a time point T(4), the engine rotation speed NE reaches the rotation speed of the 3rd-speed run.

[0060]

FIG. 5(B) illustrates the transitions of the target slip rotation speed and the calculated slip rotation speed. If the calculated slip rotation speed is greater than or equal to the target slip rotation speed, it is determined that the starting condition has been met (YES at S112), and the calculated slip rotation speed is set as the target slip rotation speed (time point T(2)). As a result, the target slip rotation speed and the calculated slip rotation speed remain to be the equal rotation speeds, respectively, during the time period from T(2) to T(3). If the converging condition is met at the time point T(3) (YES at S124), the target slip rotation speed gradually converges to the steady target rotation speed. In this case, the lockup clutch 122 is gradually engaged to a predetermined state.

[0061]

FIG. 5(C) illustrates the transitions of the oil pressures (B1 oil pressure, C1 oil pressure) of the friction engagement element and the oil pressure of the lockup clutch 122 (lockup oil pressure). On the basis of the downshift instruction (time point T(1)), the B1 oil pressure is reduced, and the C1 oil pressure is gradually increased. If the C1 oil pressure rises to such a level as to transfer torque at the time point T(2), the B1 oil pressure is further reduced. At a time point T(2'), the friction engagement element "B1" is completely released.

[0062]

As described above, according to the control apparatus of the embodiment of the invention, if a downshift is detected while the vehicle is coasting in the fuel-cut state, the calculated slip rotation speed is set as the target slip rotation speed for the lockup slip control provided that a predetermined condition is fulfilled. Since the oil pressure of the lockup clutch 122 is kept constant, a predetermined engagement state of the lockup clutch 122 is maintained. Therefore, it is possible to prevent the lockup clutch 122 from being engaged more than necessary, and at the same time, it is possible to suppress generation of shock caused by engagement thereof. However, in a shift situation that will likely lead to a complete engagement of the lockup clutch (e.g., a case where the slip rotation speed becomes less than a predetermined rotation speed), the lockup oil pressure is not fixed. Therefore, it is advantageous in that complete engagement of the lockup clutch is avoided regardless of the situation of a shift.

[0063]



Furthermore, since the lockup clutch 122 is prevented from engaging during execution of a downshift, it is possible to prevent rapid fall of the input rotation speed of the automatic transmission 200. Therefore, the input rotation speed is allowed to increase to the post-downshift rotation speed within a predetermined time, so that the downshift can be completed within that time. Hence, it is possible to provide a control apparatus of a lockup clutch which is capable of avoiding a completely locked-up state during a decelerating run of the vehicle in the fuel-cut state, preventing a delay in the downshift, and also suppressing generation of shock.

[0064]

Note that in order to maintain a predetermined state of engagement of the lockup clutch 122, it is possible to execute a control of keeping an oil pressure of the lockup clutch 122 fixed based on the calculated slip rotation speed instead of the process (S118 and S120 in FIG. 4) of setting a predetermined rotation speed as the target slip rotation speed for the feedback control.

[0065]

That is, it is also possible to execute a control of fixing the oil pressure of the lockup clutch 122 via the lockup control valve 158 if the calculated slip rotation speed is greater than or equal to the reference rotation speed (YES at S116). Therefore, a constant state of engagement of the lockup clutch 122 can be maintained, so that the downshift can be executed without a delay.

[0066]

Furthermore, the control of fixing the oil pressure of the lockup clutch 122 may be stopped if the calculated slip rotation speed is less than the reference rotation speed (NO at S116). This operation will prevent the lockup clutch 122 from being engaged more than necessary, and therefore will prevent generation of engagement shock. Furthermore, if the oil pressure fixing control is stopped, the reference rotation speed may be set as the target slip rotation speed.

[0067]

It is to be understood that the embodiment disclosed herein is merely illustrative, and not restrictive in all aspects. The scope of the invention is not defined by what has been disclosed above, but by what is claimed, and the invention is intended to cover all modifications that are equivalent to or within the scope of what is claimed.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1]

FIG. 1 is a diagram illustrating control blocks of a control apparatus according to an embodiment of the invention.

5 [FIG. 2]

FIG. 2 illustrates the configuration of a drive train of a vehicle equipped with the control apparatus according to the embodiment of the invention.

[FIG. 3]

10 FIG. 3 is an application chart of engagement elements of an automatic transmission according to the embodiment of the invention.

[FIG. 4]

FIG. 4 is a flowchart illustrating a control configuration executed by the control apparatus according to the embodiment of the invention.

[FIG. 5]

15 FIG. 5 is a time chart indicating transitions of characteristic values of a vehicle equipped with the control apparatus according to the embodiment of the invention.

[FIG. 6]

20 FIGS. 6 is a time chart indicating transitions of characteristic values of a vehicle equipped with a related-art control device.

[DESCRIPTION OF THE REFERENCE NUMERALS]

100 ECT\_ECU, 120 TORQUE CONVERTER, 122 LOCKUP CLUTCH, 124  
TURBINE RUNNER, 126 INPUT SHAFT, 202 OIL PUMP, 204 DUTY  
25 SOLENOID, 208 TRANSMISSION INPUT SHAFT

[NAME OF THE DOCUMENT] Abstract of the disclosure

[ABSTRACT]

[TASK] To prevent a delay in a downshift and generation of shock.

5 [MEANS OF SOLVING THE PROBLEM]

A control method of a lockup clutch includes a step of controlling an oil pressure for a downshift (S108) when a downshift instruction has been detected (YES at S106) during execution of a lockup slip control (YES at S104); a step of detecting a state of operation of an automatic transmission (S110); a step of calculating a slip rotation speed (S114) if a starting condition has been met (YES at S112); a step of setting a calculated slip rotation speed as a target slip rotation speed (S118) if the calculated slip rotation speed is greater than or equal to a reference rotation speed (YES at S116); and a step of converging the target slip rotation speed to a steady target rotation speed (S126) if a converging condition of the target slip rotation speed has been met (YES at S124).

15 [SELECTED DRAWING] FIG. 4

## [NAME OF THE DOCUMENT] Drawings

## [FIG. 1]

- 110 ENGINE
- 5 152 WATER TEMPERATURE SENSOR
- 154 THROTTLE OPENING SENSOR
- 156 ENGINE SPEED SENSOR
- 158 LOCKUP CONTROL VALVE
- 164 INPUT ROTATION SPEED SENSOR
- 10 166 OUTPUT ROTATION SPEED SENSOR
- 168 OIL TEMPERATURE SENSOR
- 200 AUTOMATIC TRANSMISSION
- 300 SPEED CHANGE MECHANISM

- 15 [FIG. 2]
- 1/CASING

## [FIG. 3]

- 2/POSITION
- 20 3/1ST ENGINE BRAKE
- 4/CLUTCH AND BRAKE

## [FIG. 4]

- S102 READ SIGNAL
- 25 S104 IS LOCKUP SLIP CONTROL BEING EXECUTED?
- S106 HAS DOWNSHIFT INSTRUCTION BEEN DETECTED?
- S108 CONTROL OIL PRESSURE FOR DOWNSHIFT
- S110 DETECT STATE OF OPERATION (SUCH AS OIL PRESSURE, DUTY RATIO)
- 30 S112 HAS STARTING CONDITION BEEN MET?
- S114 CALCULATE SLIP ROTATION SPEED
- S116 IS CALCULATED SLIP ROTATION SPEED  $\geq$  REFERENCE ROTATION SPEED?

S118 SET CALCULATED SLIP ROTATION SPEED AS TARGET SLIP  
ROTATION SPEED

S120 SET REFERENCE ROTATION SPEED AS TARGET SLIP ROTATION  
SPEED

5 S122 DETECT STATE OF OPERATION (SUCH AS OIL PRESSURE, DUTY  
RATIO)

S124 HAS CONVERGING CONDITION BEEN MET?

S126 CONVERGE TARGET SLIP ROTATION SPEED TO CONSTANT  
TARGET ROTATION SPEED

10 5/RETURN

[FIG. 5]

6/(A) ROTATION SPEED

7/DOWNSHIFT OUTPUT (4-TO-3)

15 8/DETERMINATION OF STARTING CONDITION (START OF INERTIA  
PHASE)

9/DETERMINATION OF CONVERGING CONDITION (DETERMINATION OF  
END OF SHIFT)

10/(B) SLIP ROTATION SPEED

20 11/TARGET SLIP ROTATION SPEED

12/CALCULATED SLIP ROTATION SPEED

13/STEADY TARGET ROTATION SPEED

14/(C) OIL PRESSURE

15/DISENGAGING-SIDE OIL PRESSURE (B1 OIL PRESSURE)

25 16/ENGAGING-SIDE OIL PRESSURE (C1 OIL PRESSURE)

17/LOOKUP OIL PRESSURE

18/(TIME T)

[FIG. 6]

30 6/(A) ROTATION SPEED

10/(B) SLIP ROTATION SPEED

11/TARGET SLIP ROTATION SPEED

12/CALCULATED SLIP ROTATION SPEED

14/(C) OIL PRESSURE

17/LOUKUP OIL PRESSURE

18/(TIME T)

19/4-TO-3 DOWNSHIFT INSTRUCTION

20/START OF INERTIA PHASE

5 21/TEMPORALILY RISE

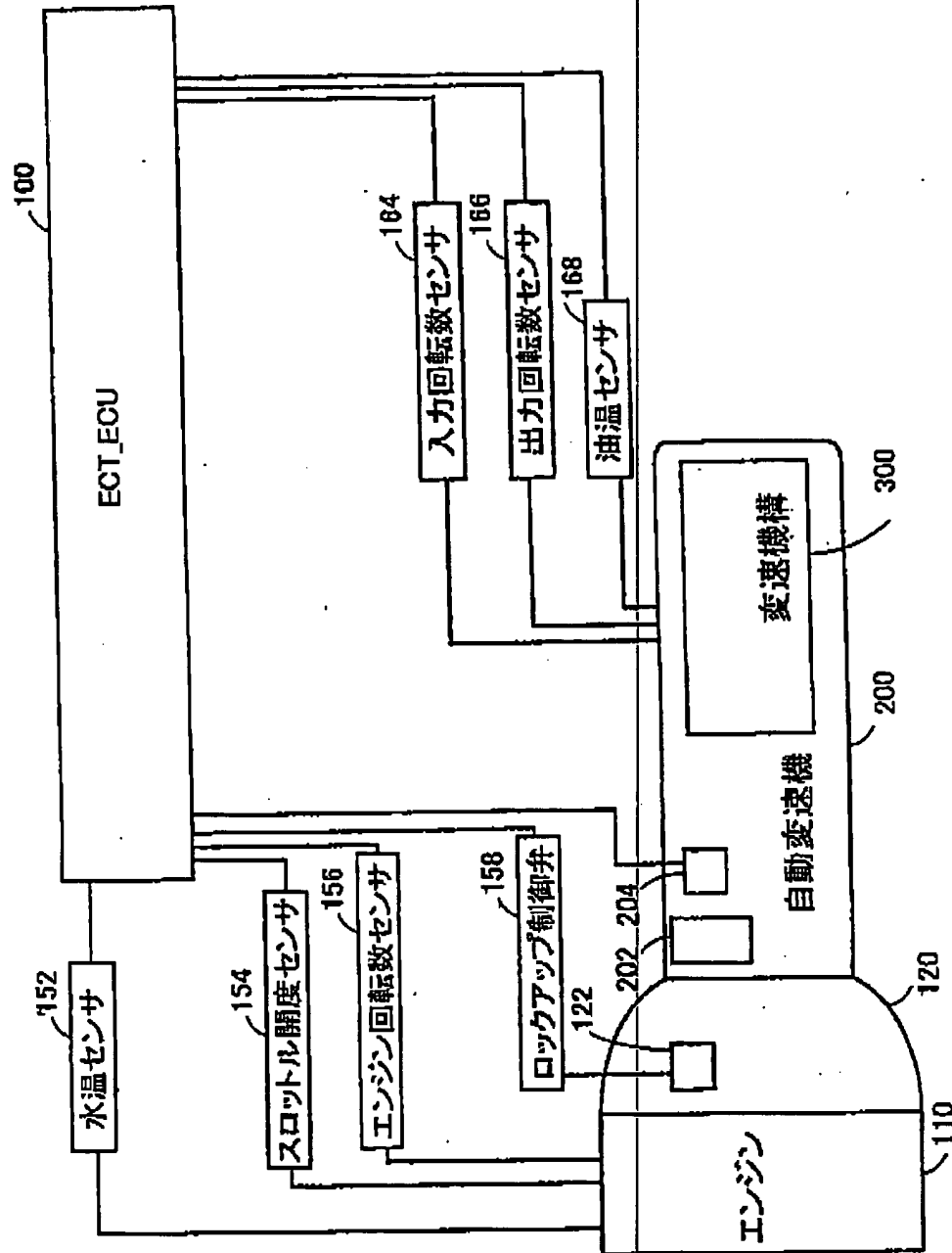
提出日 平成14年11月11日

頁: 1/ 6

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【書類名】 図面

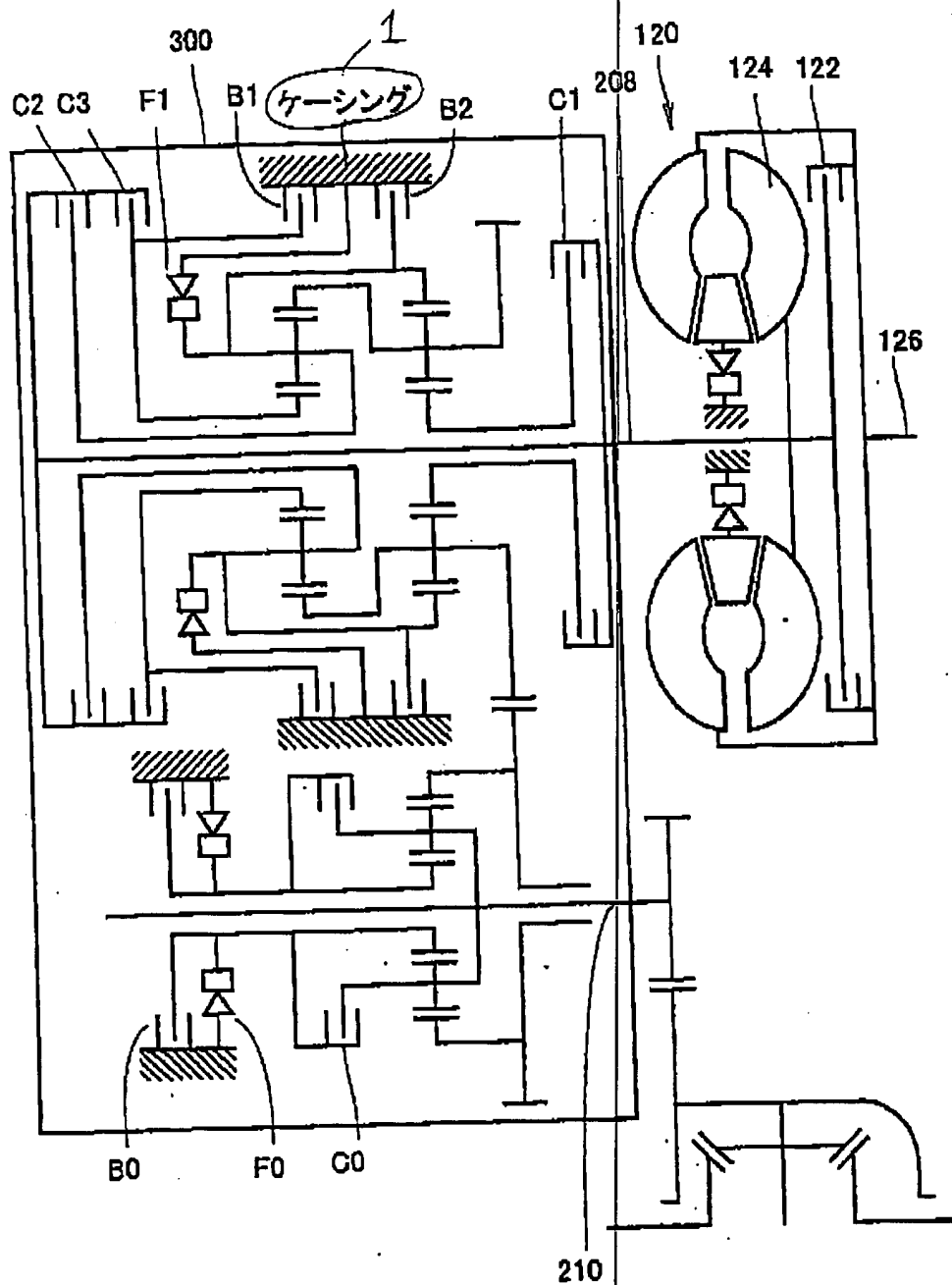
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【図2】





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【図3】

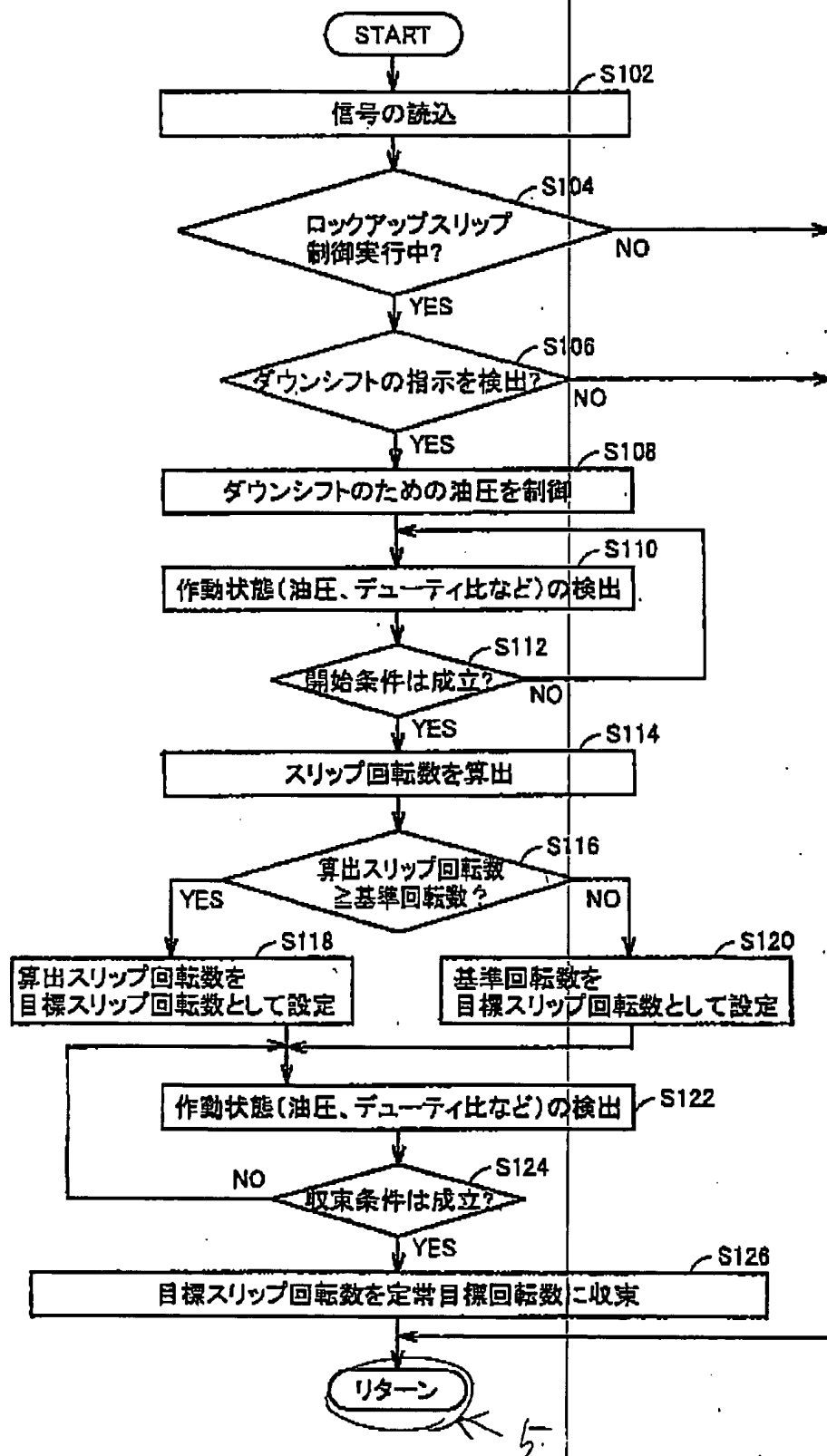
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D	1st	x	○	x	x	○	x	x	△	○
	2nd	x	○	x	x	○	○	x	△	x
	3rd	x	○	○	x	○	x	x	△	x
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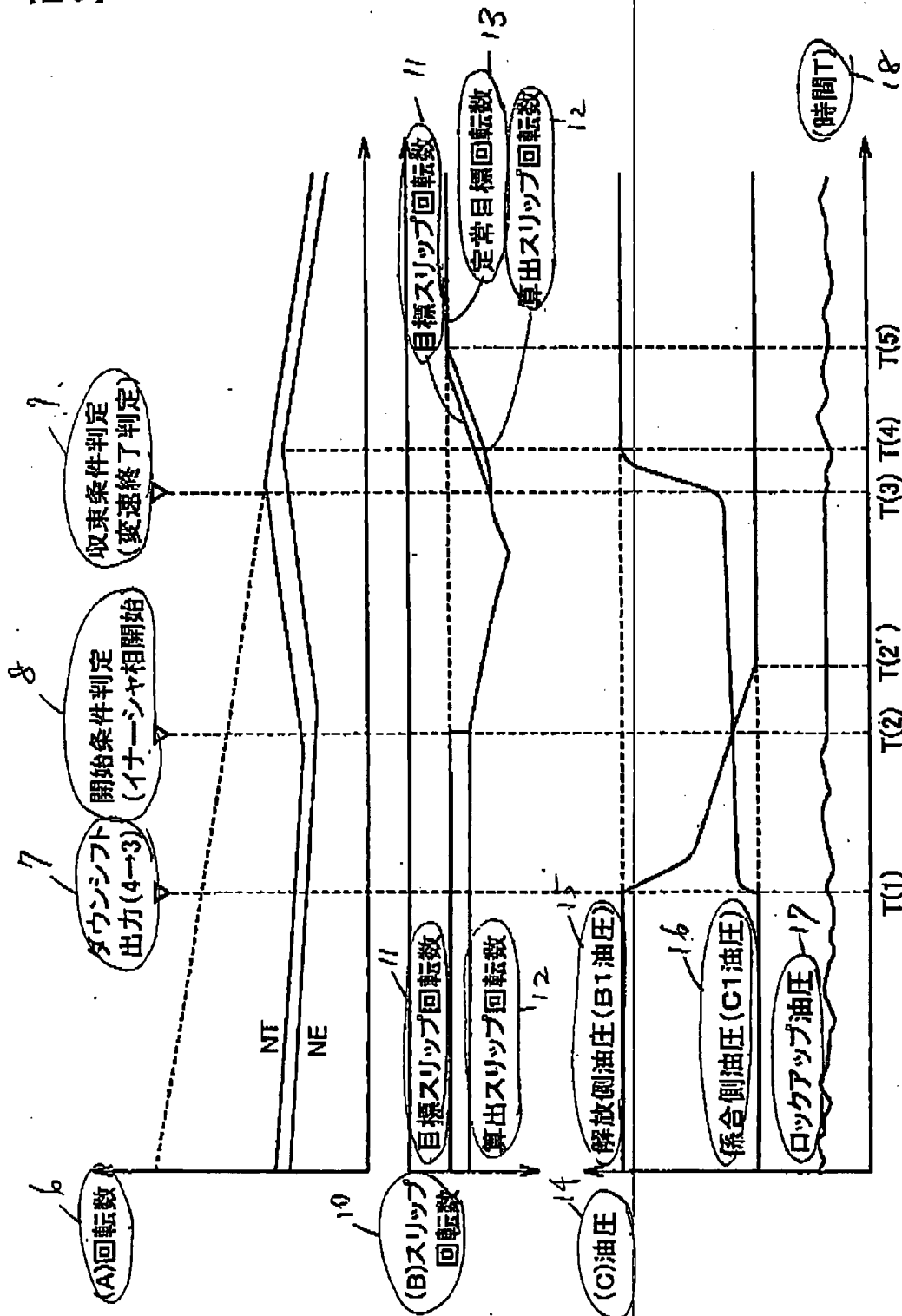


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【図5】



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【図6】

